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Energy sustainability, stakeholder conflicts, and the future of hydrogen in Denmark

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ABSTRACT

Denmark spends the most on hydrogen research (in Gross Domestic Product terms) than any other country in the world, which has led to an immense amount of activity related to hydrogen fuel cells within the past decade. However, not all stakeholders in the Danish hydrogen network share the same vision for the technology. This study therefore uses critical stakeholder analysis to first identify the most influential actors involved in hydrogen research before it documents a set of stakeholder conflicts. The study has a threefold conclusion that urges analysts to rethink how they view stakeholder contention within the Danish hydrogen research network. First, the study concludes that hydrogen and fuel cell technologies are still open for interpretation and the application is thus a conflict area between stakeholders. Second, stakeholder conflict can contribute to technical development according to an evolutionary economics perspective. Third, consensus regarding energy system transitions is by nature temporary and, at times, can be counterproductive to the advancement of hydrogen technologies.

Contents

1. Introduction

Denmark, perhaps more than any other country, has attempted to embrace a hydrogen economy. National energy plans call for an ambitious mitigation of CO_2 and a significant acceleration in the use of renewable resources. The goal for 2020 is 50% power production from renewable resources, and 35% of complete energy consumption from renewables, moving to complete penetration of renewables by the year 2050 [1]. Therefore Denmark invests heavily in research and development for renewable energy technologies. For instance, from 2000 to 2012, the Danish government has committed US$280 million of public funding into hydrogen

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research projects, the largest of any other type of alternative energy technology over the 13 year period [2]. Denmark is furthermore the country that spends the most on Hydrogen and fuel cell development worldwide measured against Gross Domestic Product (GDP) [3].

Yet despite these substantial investments, little actual hydrogen infrastructure exists, and hydrogen fuel cells remain only in isolated niche markets where customers are willing to pay a premium for the technology [4]. Even the Danish energy sector, propelled by natural gas and crude oil, retains aspects of "carbon lock-in" [5], and new energy systems, such as hydrogen, face barriers that transcend expectations, markets, institutions, and technology [6–8].

This situation is unfortunate, given that hydrogen and fuel cell technologies can offer a wide range of applications ranging from small scale supply to large scale power plants that can enable Denmark, and other countries, to respond to energy challenges [9]. Compared to the internal combustion engine, fuel cells produce no direct local emissions, are practically noiseless and theoretically more stable due to the absence of moving parts [10]. Compared to batteries, hydrogen systems have faster refueling and higher energy density, meaning they can refuel quicker and travel longer than electric vehicles [11,12].

So why, then, has hydrogen technology not taken off as expected in Denmark? This paper utilizes critical stakeholder analysis to determine how different stakeholders perceive hydrogen technology throughout the country. We define the country's hydrogen and fuel cell network as those actors who are engaged in research, development, production, financing and governing and otherwise supporting hydrogen production and handling and fuel cell technologies. Our research is based on 21 interviews with key stakeholders across 10 institutions in the hydrogen and fuel cell network conducted between September 2010 and November 2013[2]—key details of these interviews are presented in Appendix I—supplemented with a review of the academic literature and policy literature [13].

To make its case, the paper proceeds as follows. It begins by introducing readers to critical stakeholder analysis and then conducting such an analysis for the country of Denmark. Then, it presents a sample of four stakeholder conflicts including hydrogen production and handling, stationary units, mobile applications, and energy utilities. It concludes by calling on policymakers and researchers concerned about hydrogen technology to reconceptualize how they envision stakeholder cohesion and controversy.

The importance of such an inquiry is twofold. First, it has real-world practical value for Danish policymakers, helping to identify the lingering barriers that impede widespread deployment of the hydrogen and fuel cell technology. Second, it has relevance for hydrogen practitioners in any country that must manage competing stakeholder interests in an ever-changing energy technology and policy landscape. This has descriptive as well as predictive value beyond Denmark.

2. Materials and methods

The term "stakeholder" was originally defined as [14]: "Those groups without whose support the organization would cease to exist." The traditional list of stakeholders includes shareowners, employees, customers, suppliers, lenders, and/or society. In this paper we will include the stakeholders mentioned in the citation above, and we will apply a selection criterion where we include those stakeholders who have the power to exert influence over the development of the innovation system.

In addition, stakeholders can be divided into "internal," "external," and "rest of world" categories. The "internal" stakeholders are those directly involved in the utilization of a particular event or technology, whereas the "external" stakeholders are those not directly involved but who still are critical to the development of the technology. Examples include promoters of a competitive technology, educators that may need to teach students about a technology, insurance companies that need to indemnify against liability, and so on. "Rest of world" are actors who cannot influence any meaningful development, meaning they are peripheral and need only be monitored sporadically [15]. Stakeholders can further be classified according to their involvement in the decision-making processes. Mitchell et al. [16] use the three metrics of power, legitimacy and urgency.

The purpose of conducting the stakeholder analysis is to examine relevant stakeholders to a given technological or political field, and subsequently account for their interests and relative power [17]. As Brown and Sovacool [18] write, the process involves:

- Identifying relevant stakeholders to include for analysis.
- Assessing each stakeholder's objectives, interests and beliefs.
- Characterizing stakeholder resources.
- Elucidating the strategies and venues stakeholders use to achieve their objectives.

The purpose of applying critical stakeholder analysis in this manner is to enable a more efficacious management of stakeholder interactions [19,20].

3. Results

Who, then, are the stakeholders within the Danish hydrogen and fuel cell innovation system? The Danish Partnership for Hydrogen and Fuel Cells consists of 15 producing companies, three formal networks of which one is an overall industry association, four universities and three institutional units [21]. In addition to these there are exogenous actors and institutions that have an indirect influence on hydrogen development.

As mentioned in the previous section, stakeholder identification in the broadest sense includes all actors or groups who can affect the objectives of an organization's (or in this case an innovation system's) achievements or can be affected by the objectives of the organization. When applying this perspective the group of Danish hydrogen stakeholders it can expand, arguably, to include all of society, considering that hydrogen and fuel cell technology can revolutionize the entire energy system including power and heat production, transportation and commerce, and household energy use. So a loose definition of a hydrogen stakeholder could encompass everyone. Although there is widespread agreement that the fossil energy system will not be replaced directly by a hydrogen economy [22], the technology can play an important role in the future energy system [9]. To narrow within such a large group, we have therefore in this section included only the actors which we consider most influential for the development of the hydrogen and fuel cell innovation system, and for the development of the energy system. We do this by classifying stakeholders based on their power, legitimacy and urgency, considering a stakeholder salient if they possess at least two out of these three criteria. Only if the

[2] The research has been conducted as a qualitative case study, where data have been gathered through a number of channels. Primary sources of data were gathered through unstructured informal interviewing of key actors within the Danish energy system and hydrogen and fuel cell network. Furthermore, knowledge gathering has been conducted through participation in open meetings at the Danish energy agency and at the Danish Partnership for Hydrogen and Fuel Cells. Lastly, knowledge concerning the Danish competitive capabilities has been gathered through participation in industrial fairs.

stakeholder possess at least two of these attributes will the stakeholder salience be high [16].

Table 1 presents the results of our critical stakeholder analysis. In it, we present 21 of the most influential actors which have been selected on the basis of their engagement activities in Danish research development and demonstration projects. As mentioned earlier, our list of stakeholders is derived from both an analysis of research, development and demonstration (RD&D) activities as well as an investigation through interviews and observations conducted in the Danish energy industry.

As readers digest Table 1, we must mention that our list of stakeholders contains primarily active proponents of the hydrogen and fuel cell innovation system; no opponents were identified. We must also mention that most of the actors fall into the private sector, including primarily companies working for the production and utilization of hydrogen and fuel cell technology, and the networks in which the companies and institutions are formally arranged. There was little to no participation identified from civil society or consumer advocate groups.

4. Discussion

Though they do have a set of interests and agendas that align, our stakeholder assessment also reveals that at least four significant areas of tension exist related to hydrogen production and handling, stationary units, mobile applications, and utility companies. This section discusses each of these in turn.

4.1. Hydrogen production and handling

Within the realm of hydrogen production and storage, there is still no consensus on whether there should a centralized or decentralized network for hydrogen. According to one of our respondents, a participant from H2 Logic A/S, a hydrogen filling station manufacturer in Denmark, “there is no political will to establish a centralized hydrogen production and distribution system today. Therefore the hydrogen filling stations are being built with water electrolysis at existing sites.” A centralized system could benefit from large scale hydrogen production which could achieve economies of scale. The main challenge for this system relates to the distribution of the produced hydrogen. Tests from the Danish Gas Technology Agency have shown that the established gas grid is capable of transporting pure hydrogen through their existing network. The problem, however, is that the boilers installed at combined heat and power plants are not capable of running on hydrogen gas. Therefore the use of hydrogen gas in the natural gas grid will require membranes which can separate the natural gas from the hydrogen gas at the point of use. These will have to be designed for this specific purpose though. Conversely, as the volumetric energy density in hydrogen is approximately half of the energy density in natural gas, mixing hydrogen into the natural gas grid will thus reduce the energy transfer capability of the system, and this conflicts with the interests of Energinet.dk.

We see a similar degree of contention concerning storage. In Denmark, there have traditionally been several methods in use over the past few decades: traditional pressurized hydrogen gas, cryogenic liquid gas and metal hydride storage. The most appropriate storage method depends on the application, where pressurized hydrogen gas (or synthetic natural gas) today is preferred for large scale storage in low pressure caverns or in small scale in high pressure vessels for vehicles, cryogenic liquid gas for transportation of large volume on road or rail, and metal hydride storage when volumetric hydrogen content is important for transportation purposes in the future. An on-going research project in Denmark between industry and university is investigating the possibility to combine pressurized gas and metal hydride storage technology [23]. The prospect for this project is to combine the strengths of each of the technologies, in order to increase volumetric energy density, and to avoid the high heat generation when pressurizing, which can be problematic for hydrogen vessels utilizing internal plastic liners. This is especially applicable for transportation purposes. Yet, admittedly, the project is still at a nascent level and the timeframe for mainstream application remains distant.

A final source of tension concerns the competition hydrogen and fuel cell technology faces, compared to other options, in the arena for the future sustainable energy solutions. Denmark has vast “clean” energy resources, amongst these biogas and wind power. The vision for large scale deployment of wind energy requires however energy storage solutions and this is where hydrogen can be utilized as medium in the establishment of power to gas solutions, where CO_2 is hydrogenated with electrolysis-generated hydrogen. Indeed, biogas and the synthetic fuels compete politically for financial support, both in terms of support for RD&D and in terms of feed-in tariffs. Biogas receives a subsidy of 101–115 Danish kroner (DKK) per GJ of gas supplied to the grid, whereas neither the production of natural gas through hydrogenation of CO_2 nor the production of pure hydrogen gas receive any subsidy [24]. Some stakeholders have argued that this hinders the equal competitive conditions in the commercial market for hydrogen technologies.

4.2. Stationary units

A second source of conflict involves how stakeholders perceive opportunities for stationary use in Danish homes. One significant obstacle for stationary micro-combined heat and power (μCHP) technology in Denmark is related to the fact that 60 percent of all private houses are connected to centralized district heating grid [25]. Thus, many levels of Danish society—including energy suppliers, municipalities and communes, and ordinary household consumers—both prefer and remain dependent on non-hydrogen produced and distributed heat. Converting to hydrogen, for them, would be needlessly expensive. For the remaining 40 percent of Danish homes, stakeholders remain divided over which decentralized technology to use, with many favoring conventional heat pumps [25]. The utility companies SEAS-NVE, EnergiMidt and Dong Energy have all expressed varying degrees of interest, and commitment, to the development of hydrogen and fuel cell μCHP technology. According to one interviewee the strategic goal is “to implement the technology in an Energy Service Company (ESCO) framework, where the units installed at the consumers can be controlled locally and thus be used to balance the localized energy grid.” Yet the Danish Energy Agreement from 2012 has allocated 42 million DKK to replace conventional oil and gas boilers with a variety of technologies that may compete with each other, including geothermal heat pumps, solar panels, and solar water heaters [1].

Similarly, stakeholders remain divided over the issue of subsidies. Some actors argue that hydrogen, like other alternative sources of energy, should be highly subsidized; others posit that subsidies should be removed so that hydrogen and fuel cell technology can compete by itself in a purely commercial market. Advocates of the subsidy approach point to the very successful ENE.FARM project in Japan as an example, where more than 30.000 fuel cell μCHP units have been installed [26–28]. This high number gives producers incentives for investment and leads thus to rapid technology improvement and accomplishment of economies of scale. In Denmark a demonstration project comprising installation and testing of 30 μCHP fuel cell units have been on-going since 2006 [29,30], and the Danish companies engaged in this project are among the technology leaders in Europe, and have been invited to a European multinational project with the target to

Table 1
Critical stakeholder assessment of the Danish hydrogen and fuel cell network.
Source: authors.

Type of actor	Actors	Objective with regards to hydrogen and fuel cell technology	Power
Network organizations	Danish partnership for hydrogen and fuel cell technology	Development and distribution of hydrogen and fuel cell technologies through triple helix cooperation (government, universities, industry)	Political influence on both national and European level
	HydrogenLink	Platform for establishment of a Scandinavian hydrogen highway	Key influential actor in the development of Nordic hydrogen infrastructure
Institutions	Danish energy agency (EUDP)	Technology development to reach maturity	High impact on development. Directed by the Danish Ministry of Climate, Energy and Buildings Governmental direction of development Funding of politically prioritized technologies
	Energinet.dk	Interest in stabilizing the Danish power and gas grid	Highly influential in the development of the Danish Energy System. Has created a vision for integrating the electrical- and the gas grid through amongst others hydrogen and fuel cell technology.
	Danish Technological Institute	Facilitates knowledge dissemination activities through participation in research development and demonstration projects	Key actor in knowledge development processes. Actor among the technology leaders. Can exert power through selection of research projects.
Institution /corporate stakeholder	Danish Gas Technology Center	Consulting and development company within gas utilization projects	Certification, advisor for legislative action
Corporate stakeholders	H2 Logic A/S	To develop and produce hydrogen filling stations and fuel cell power packs to utility vehicles	Influence on formulation of the European research program for hydrogen and fuel cell technology Collaboration and MoU with leading car manufacturers for development of hydrogen and fuel cell cars
	IRD	Development and commercialization of PEM fuel cells and DMFC and electrolyzers	Limited power. Can exert the power through the partnership for hydrogen and fuel cells
	Serenergy	Development and commercialization of HT-PEM fuel cells with methanol reformers	Limited power. Can sometimes exert their power through the partnership for hydrogen and fuel cells, and through the market, given that this company has a high degree of commercial activity compared to other corporate stakeholders
	Haldor Topsøe / Topsoe Fuel Cell	Development and commercialization of SOFC and SOEC	Limited power. Has the advantage of being owned by a large company (Haldor Topsøe), with the power to finance development activities which are needed at this point
	Dantherm power A/S	Commercialization of PEM fuel cell applications	Owned by the global leader within the PEM fuel cell technology. High level of commercial activities, and has hence the power of being (one of) the market and technology leader(s) in Denmark
	GreenHydrogen	Development and commercialization of alkaline electrolyzers for hydrogen production	Key player within electrolysis activities. Has limited influence on the innovation system development.
		No objectives with regards to fuel cells. Hydrogen can just as well be burned in gas turbines	High influence on the technological development for hydrogen production.
	(Oil Companies: OK A.M.B.A, Statoil)	Investing in potential future energy medias. Primarily Methanol	Has established infrastructural network. Has potential influence on the type of fuel to be used for fuel cells for transportation
Universities	Technical University of Denmark	Leading research facility in: alkaline electrolysis and SOFC Fuel cell technology	Influence on the technological development trajectory.
	Aalborg University	Leading research facility in PEM fuel cell technology, and involved in a number of research and development projects	Influence on the technological development trajectory.
	Aarhus University	Focus on hydrogen production through alkaline electrolysis and on hydrogen storage in metal hydrides	Influence on the technological development trajectory.
Utility company	Dong Energy	Focus on conventional technologies, has recently left the Danish partnership for hydrogen and fuel cell technologies	Powerful actor. Largest utility company in Denmark
	SEAS-NVE	Energy supplier. Interested in fuel cells for micro-combined heat and power solutions. ESCO type of arrangement to earn on heat supply	Limited power, but can in time be a game changer in the Danish Energy supply system, if FC-μCHP will have commercial breakthrough.
	TRE-FOR	Energy supplier. Interested in fuel cells for micro-combined heat and power solutions. ESCO type of arrangement to earn on heat supply	Limited power, but can in time be a game changer in the Danish Energy supply system, if FC-μCHP will have commercial breakthrough.
	EnergiMidt	Energy supplier. Interested in fuel cells for micro-combined heat and power solutions. ESCO type of arrangement to earn on heat supply	Limited power, but can in time be a game changer in the Danish Energy supply system, if FC-μCHP will have commercial breakthrough.
Industry association	Danish Energy Association	Actively involved in The Danish Electric Vehicle Alliance	Highly influential actor. Has political power to promote competing technology

deploy 1.000 units in total [31]. To distribute more would require prohibitively expensive subsidies. The advocates of removing subsidies point instead to regulation and the necessity of taxing or dis-incentivizing unwanted environmental behavior. This action would result in higher energy prices (that now more accurately reflected externalities) but prices are also more, to a certain degree, equitable.

4.3. Transportation and mobile applications

In most countries, the issue of hydrogen powered transport faces a "chicken and egg" problem [32]. Consumers will not buy a hydrogen car before the infrastructure is established, and the infrastructure will not be established before the cars are on the market, a problem that even the internal combustion engine faced at the turn of the previous century [33]. In Denmark mobile applications of hydrogen and fuel cells face an additional challenge; automobile manufacturers and Danish companies and network units have signed a memorandum of understanding for establishment of hydrogen infrastructure, intending to demonstrate Scandinavia as one of the early markets for the hydrogen and fuel cell car, yet this agreement is based on goodwill between the companies, rather than any formal obligation, and stakeholders (again) disagree about which low-carbon technologies to fully endorse.

For instance, many stakeholders that we consulted suggested that the "real long term competition" was between battery electric vehicles, the natural gas driven car, and the hydrogen and fuel cell vehicle. The natural gas driven car has potential to gain influence due to the Danish gas grid being extended to cover the entire country, and does not suffer from lack of infrastructure as the other two technologies. The introduction of the battery electric vehicle to the Danish market is supported by the Danish Electric Vehicle Alliance which is an independent trade organization under the Danish Energy Association as well as the biggest Danish utility company, Dong Energy (which literally stands for Danish Oil and Natural Gas). Dong Energy has invested substantially in establishment of electrical vehicle infrastructure in collaboration with the now bankrupt Israeli company Better Place. There is thus a significant amount of stakeholder fragmentation and disagreement, even *within* some of the same companies. Contributing to the lack of coordination, rather than "pick one," the government has chosen not to focus on any specific technology. Funds have been allocated for infrastructure that would support each of three distinct technological pathways. Stakeholders, perhaps rightly so, seem unwilling or unable to navigate such "intrinsically diverse" transportation pathways that are, to a large extent, incommensurable with each other.

4.4. Utility companies and energy dependence

A final stakeholder conflict involves Danish utility companies which are faced with a massive balancing task for the national energy system. As mentioned earlier, according to the official Danish energy strategy 50% of electricity supply should in 2020 come from wind power. This engenders a complicated technical challenge in terms of balancing and storing different forms of electricity produced in different ways at different times [34]. Furthermore, the current governmental agreement on energy policy in Denmark states that heat and power production should be 100% "sustainable" in 2035. The conflict within this domain relates to whether that future energy solution should be designed as a domestic stand-alone solution or based on an extension of the connection to the neighboring countries. One of the key options pursued today is to enhance power exchanges with the Nordic countries. Norway has extensive hydropower capacity which can be controlled and utilized when needed. The risk however is that the excess power which Denmark produces in times of high wind supply is sold at a low price (or even negative price), in contrast to the power imported to Denmark from neighboring countries which is often bought at higher rates.

Thus, an alternative domestic solution for Denmark would be to establish systems that can store electricity. Technically hydrogen can do this through a number of different pathways. The most prominent of these is the process of power to gas, where hydrogen is produced from electrolysis and reacts with CO_2 (e.g. from air, biogas, coal power plants or industry) to produce synthetic natural gas. The problem at this point is that stakeholders are divided over whether or how a large scale facility can provide this type of balancing efficiently and affordably. The tension is thus concentrated on whether to keep the energy balancing domestic or whether to trade the electricity with neighboring countries in the future [37,38]. Through the actions of Energinet.dk, the public owned grid operator, it seems as if there is deep internal disagreement, given that the organization invests heavily in expanding both natural gas and electrical grid to neighboring countries, but at the same time gives funds to projects that can make these additional connections unnecessary.

As a sign of how serious these stakeholder disagreements can become, Dong Energy withdrew their membership in the Danish Partnership for Hydrogen and Fuel Cells in 2013. Dong Energy, the largest energy company in Denmark, has a stated vision of going from 80% fossil and 20% renewable energy to 80% renewable and 20% fossil in 30–40 years. Their withdrawal sent an important signal to the industry that they do not see the hydrogen and fuel cell technologies (for the moment) as lucrative low-carbon investment areas, opting instead to pursue infrastructure for battery electric vehicles. Dong Energy claimed it was not "cost effective" for Denmark today to construct hydrogen facilities to enter the market for storage, creating disharmony within the national hydrogen research network.

4.5. Summary

Table 2 provides a list of the most influential stakeholders involved in the development and innovation of fuel cells in Denmark. It encapsulates poignant areas of stakeholder conflict, and it also illustrates that Danish stakeholders remain divided over at least four key areas: hydrogen production and handling, stationary units, mobile applications, and domestic versus interconnected regional supply.

5. Conclusions and policy implications

With this paper we have defined the crucial areas of stakeholder conflict within the hydrogen and fuel cell system in Denmark, and we have provided a starting point for national actors desiring to formulate strategies that can overcome obstacles. For analysts interested in the innovation of hydrogen fuel cells more generally, however, we advance three salient conclusions.

First, and most relevant for hydrogen practitioners in Europe and other industrialized countries, some areas of contention are common for each of the technological domains investigated. That is, they cut across different sectors and dimensions simultaneously. Because hydrogen and fuel cell technology is not yet sufficiently mature to replace conventionally used energy systems in their entirety, it lacks what historians of technology call "closure" [35]. The technology is still "open" to interpretation and that flexibility can breed conflict rather than consensus. As such, hydrogen stakeholders ought to be wary; they should view the technology and its applications as contested, politicized, and uncertain, its future development unlikely to appease all or even

Table 2
Stakeholder conflict within the Danish national hydrogen research network.
Source: authors.

Technological domain	Conflict
Hydrogen production and handling	Centralized or decentralized hydrogen production and distribution Subsidies given for hydrogen and upgraded natural gas or to the competitive technology biogas
Stationary units	Which technology should replace conventional oil and gas boilers in residential buildings Is it most beneficial to subsidize technology for development or to regulate against unwanted technology
Transportation and mobile applications	Which technology should replace incumbent fossil based vehicles (battery electric vehicles, gas driven cars or hydrogen and fuel cell cars) Who bears the responsibility for infrastructure establishment–is it a governmental or private actor task
Utility companies and energy dependence	Should the balancing of the future sustainable electric system be based on domestic standalone solutions or on electricity exchange with neighboring countries including Scandinavia, Germany and Great Britain

some of the most influential stakeholders. Even those who support hydrogen research can remain divided over issues of price and performance measures, where configurations of hydrogen technologies can fulfill a few specified uses but are unable to meet all of the expectations or important criteria that have been embraced by political, academic, and industrial stakeholders.

Second, and most relevant for analysts of technological innovation as well as research managers, the types of stakeholder disagreement we have identified may not be “bad” for the hydrogen research network. Indeed, one way of interpreting stakeholder conflict is Darwinian as described in the theory of evolutionary economics: stakeholders are in the process of evolving and narrowing technological designs so that “only the fittest can survive.” Put another way, stakeholder contention is strategic, rather than dysfunctional, and hydrogen's development is based on co-evolution and selection of the technology that corresponds best with the current system. Stakeholders are in the process of experimenting with different strategies which can, in the long run, only serve to make the technology more resilient and competitive. As such, stakeholders are “strategically malleable” over which particular hydrogen pathways to endorse. This approach implicitly recognizes that no single technology can replace the fossil energy regime (e.g. [36]); instead, one should expect several technological solutions to prevail in the future system. Thus, Danish planners and investors may want to consider endorsing a basket of different hydrogen applications and configurations, supporting “open” rather than “closed” innovation and development [39]. This portfolio strategy of funding, by not picking explicit winners, can enable inventors and entrepreneurs to experiment, diversify, and innovate from the ground up until more “closure” is attained. Such a portfolio strategy may also want to consider hybridizing hydrogen systems with other low-carbon sources of energy such as wind turbines, solar panels, and biogas, treating them as potential mutually beneficial collaborators rather than zero sum competitors.

Third, and most relevant for those interested in managing stakeholder conflict: when a technology such as hydrogen is at such a nascent stage of technological development, when it must “compete” with a variety of other systems in the Darwinian struggle mentioned above, then consensus may not only be impossible; it may be counterproductive. As the recent withdrawal of long-time hydrogen supporter Dong Energy from the national hydrogen network indicates, energy goals are constantly moving targets. Though more research interviews would need to be conducted to fully confirm this point, our initial data collection suggests that Danish priorities are always shifting, and stakeholder agreement on energy issues—given their political nature, given the variety of separate pathways that exist for producing low-carbon energy—will perhaps always remain ephemeral. Within the realm of energy innovation and transition, then, stakeholder contention ought to be expected and planned for. Consensus, whenever it exists, is fleeting and fragile, and so researchers ought to prepare themselves for less of it, rather than more.

Appendix A. List of interviewed companies, associations and institutions.

Date	Institution	Number of interviews
February 2012 and April 2013	Danish Partnership for Hydrogen and Fuel Cells	3
September 2012 and November 2013	H2 Logic A/S	1
April 2013	GreenHydrogen	1
April 2013	Serenergy	2
June 2010 and September 2011	Dong Energy	1
July 2013	Energinet.dk	3
September 2010	Danish Technological Institute	3
January 2013 and September 2013	Technical University of Denmark	2
November 2012 and October 2013	EnergiMidt	1
September 2011 to November 2013	Aarhus University Department of Chemistry	4
Total	10	21

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